Automatic Milking Systems

Innovative Technology for the Dairy Farm of the Future?

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Abstract

Automatic Milking is more than only using the robot for attaching the teat cups. Application of automatic milking on dairy farms has more or less the effect of a complete turnover in the overall management. Because there is in principle no supervision during milking, milk quality, cow routing, and milking frequency also requires automatic control and monitoring.

Different forms of automatic milking devices are used in research experiments and in practice. The outlines of the research on cow-routing, milking, frequency and management carried out so far were given. Improving the technology for attaching the teat cups is required before the dairy farmer can benefit completely from automatic milking.

Key words: Automatic milking, milking frequency, milk quality, lay-out cowhouse, management

Introduction

Going back into the history of machine milking Dodd & Hall (1992) note that the modern milking machine was invented a century ago! It was pioneered in Scotland, refined in Australia and perfected in many countries, particularly in New Zealand, U.S.A., U.K. and Sweden. The story is remarkable. No other machine in livestock farming has such a close biological association! During the first half of this century, machine milking was largely ignored as a research topic and progress depended largely on the ideas of inventors and manufacturers.

In many institutions and company laboratories research is being done on a large variety of technical and biological themes related to the milking process. This contrasts favourably to the first half of this century. The physiological and behaviourial aspects of automatic milking systems in connection with high-yielding cows require the attention of the relevant scientists. These aspects are crucial if we are to improve health, welfare and productive lives of the most important production factors in the dairy operation: the cows.

Besides the technological innovation of machine milking there have been other innovations as well. One can mention the cubicle house system, new designs of milking parlours, the application of animal identification systems and the milk flow meter.

The Automatic Milking System (AMS) is the latest step towards the complete automation of the milking process. It reduces the work load of the dairy farmers and is beneficial for the cow as well. Moreover, it is no longer necessary to milk at set times.

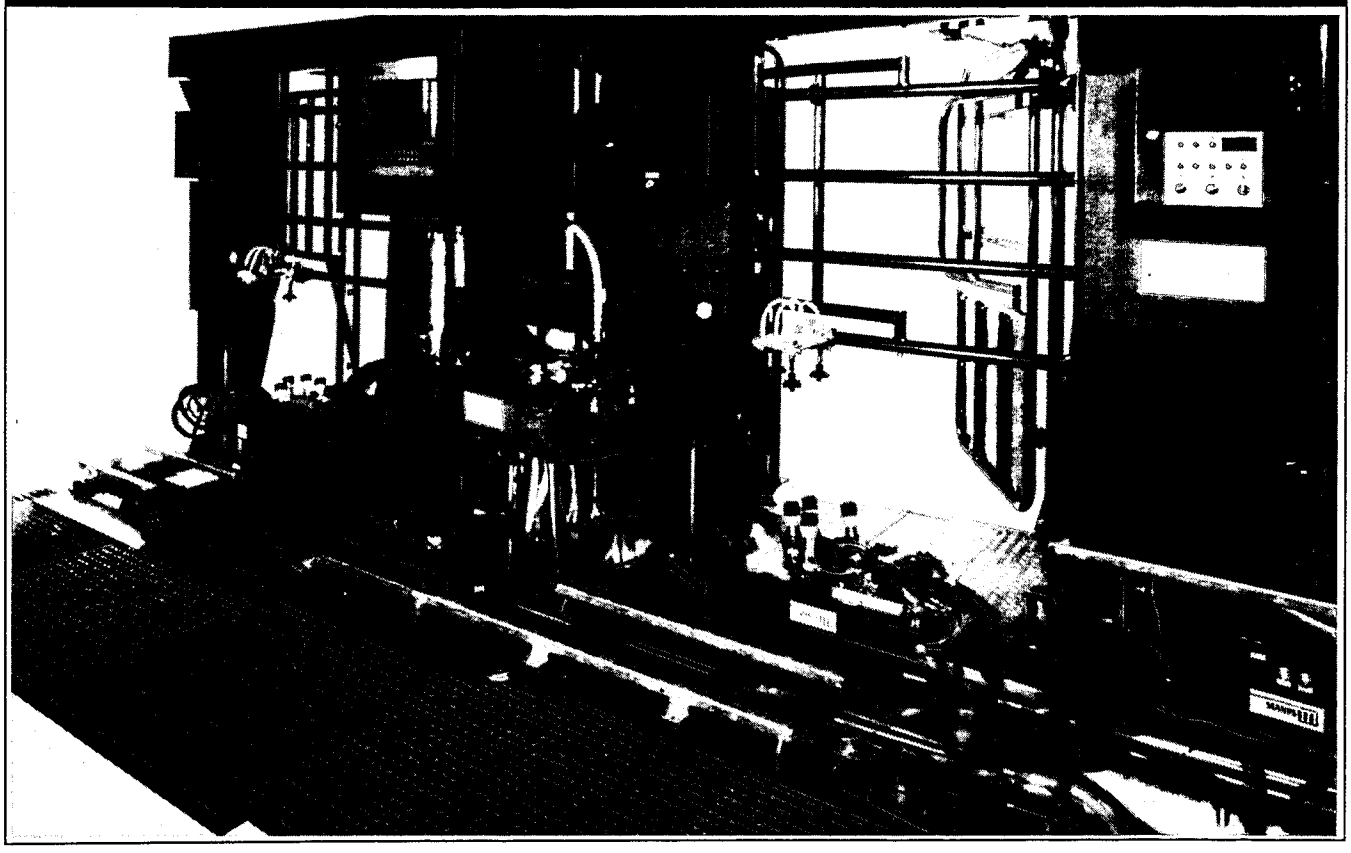
Farm 2000

Carrying out the feasibility study 'Farm 2000' (B 2000) on automation and robotization has been an important step in the development of automatic milking. This study was done in cooperation with the companies NEDAP, VICON, Dutch Herdbook Association (NRS) and the DLO-Institute of Agricultural and Environmental Engineering (IMAG-DLO). Overall goals of the feasibility study were reduction of production costs and improvement of product quality through an integral approach of process control on feeding and milking. Connected with this study project the first experiments on robotic milking have taken place in the Netherlands. Continuation of the research and development activities in the area of automation in dairying was supported by the results of the feasibility study.

Technology and Techniques

In the Netherlands automatic milking systems are currently being developed by three commercial companies, namely Gascoigne Melotte, Lely and Prolion.

Figure 1 - Overview of the Prolion AMS with two stands and one robot/sensor unit.



The automatic system, developed by Gascoigne Melotte, attaches the teat cups from behind the cow, between her hind legs (van der Linden & Lubberink, 1992). The coordinates of the teats are stored in a computer database. Before the teat cups are attached they are correctly positioned. Then the arm bearing the four teat cups approaches from the rear and attaches the cups. After the cups have been attached the database is updated with new teat coordinate data.

Prolion has built a special container in which all the necessary equipment is housed (Bottema, 1992, Hogewerf et al. 1992) (see Figure 1). In this system all the teat cups are on a milk rack and they are attached from the side, after two sensor units have located the teats. The first unit composing of two ultrasonic sensors with a diverging field has to find the correct place of the front right teat as a reference. The second unit, an ultrasonic sensor, called the fine sensor, moves up and down and has a rotating field. It measures the distance between the teats and the reference teats.

Lely Industries has built a milking robot which functions similarly to the Prolion unit. It also attaches the teat cups from the side of the animal, this time after a laser sensor has located the teats. There are also automatic milking systems in the making in other European countries.

The AMS developed by CEMAGREF in France has four arms, one for each teat cup. The arms for the front teats approach from the sides, and those for the rear teats come up from the floor (Marchal et al, 1992). Teat position is established by a global sensor and a local sensor. The three-dimensional vision system is based on the triangulation principle and uses a CCD camera and laser. The local sensor is a network of infra-red-emitting and photo transistors around each teat cup.

The system developed by the Silsoe Research Institute in England uses a pneumatic robot to do the attaching (Street et al., 1992). The position of the animal is detected by sensors which are pressed gently against the animal's flanks and back. A matrix of 8 infra-red light beams is arranged across the top of the end effector to detect the teat and allow the robot's position to be corrected until the cup is centred on the teat. The four teat cups are attached one by one by means of the robot arm.

Düvelsdorf in Germany developed a system with a frame in which an arm is moved by electric motors (Dück, 1992). Data on the positions of the teats are stored in the computer database. The arm brings the teat cups into these positions and the exact position is established by an ultrasonic sensor and light barriers. The robot arm attaches the four teat cups one by one.

The Federal Research Institute for Agriculture in Braunschweig-Völkenrode (Germany) has also developed and tested an automatic milking system (Artmann, 1992). This robot has three linear axes and one rotary axle, all driven by asynchronous motors. The clusters are attached one by one. Ultrasonic sensors, a CCD camera and a laser are used to locate the teats.

The application of robotics in agriculture is more complex than in industry. Animals are mobile, of variable structure and respond dynamically (Wathes, 1993). Because unforeseen events may occur safety of the devices is an essential requirement

(Street et al., 1994). The knowledge concerning the performances of the automatic milking systems is rather poor.

Technical performance

The success of the attachment of the teat cups is a crucial element in the reliability and general applicability of automatic milking in dairying. Success depends on cow behaviour, udder shape, teat angles, the distance between the teats and the floor and the milking interval. Besides the success rate, the number of attempts necessary for automatic milking is important. The number of attempts necessary for one automatic milking is correlated with the capacity of the system, and possibly with the milk ejection reflex, too.

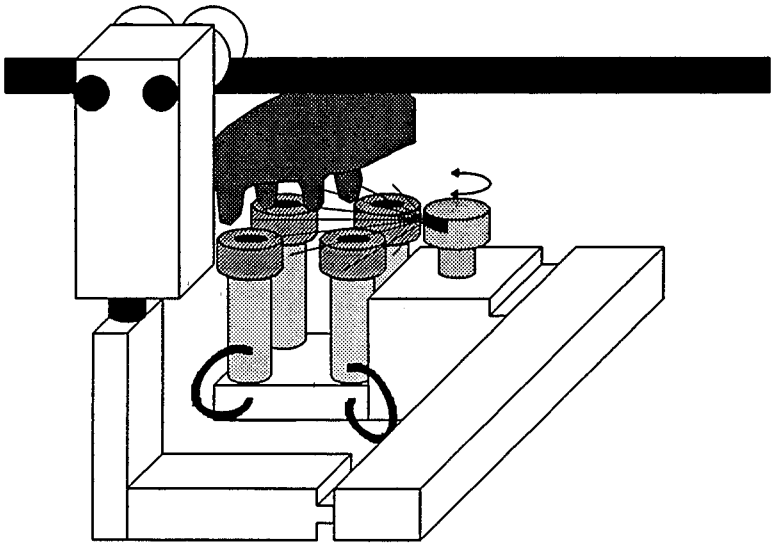
The rates of success of the different automatic milking systems vary from 64% tot 99.1% (Hogewerf et al., 1992; Marchal et al., 1992). Also the time needed for one automatic milking shows large variation, namely from 35 to 187 seconds (Hogewerf et al., 1992). Most of these figures were taken from the papers presented at the International Symposium on Prospects for Automatic Milking (1992).

High rates of success are not exceptional but for practical application it is necessary to achieve a stable and reliable success rate of the attachment technique. The so-called second generation of attachment technology must be better adapted to the differences in udder shape, udder volume in relation to lactation stage, milking interval and teat location.

Application of automatic milking devices

Practical application of automatic milking systems is still in the phase of the "early adopters" of this type of automation. Automatic milking equipment has been implemented on approximately 35 experimental farms and practical farms. Practical experiences of dairy farmers are very essential for the improvement of the commercially available systems. At the moment we can distinguish between semi-automatic and fully-automatic systems. Semi-automatic means that the dairy farmer organizes the cow-traffic and supervises the attachment routine of the system in particular. Some of the systems on practical dairy farms function according to this pattern. However, there is a tendency to go as fast as possible to fully-automatic application without supervising. Selection of the dairy cows before milking is carried out in a special selection unit (SU, see Figure 3).

Figure 2 - Diagram of the infra-red sensor, the robot with milk rack and the teat cups of the Lely milking robot system.



Integration of automatic milking on the dairy farm

For the sake of clarity it should be emphasized that an automatic milking system is more than only a robot for cluster attachment. It also includes the design of the milking place, the routing of cows towards the milking location, the rules of selection and treatment of cows, the integration of intelligent systems of monitoring cows (Prospects, 1992).

Important factors for the management of an AMS are the milking frequency, cow visits to the milking parlour, health control (mastitis) and oestrus control, milk quality control, feeding of concentrates, forage supply (e.g. grazing) and lay-out of the low house. Various processes can be monitored and controlled automatically together in an integrated stand-alone system for automatic milking, feeding and other elements of animal care. The farmer has the role of supervisor and obtains full reports of the herd from a personal computer as often as he wants. He may change process parameters and management rules, and he takes care of individual cows that need special treatment (e.g. insemination, veterinarian investigation). Optimal integration of automatic milking in the total farm management will not only save time and may improve the farmer's quality of life, but it may also improve production efficiency and the health state of the herd (Prospects, 1992; Devir et al., 1993).

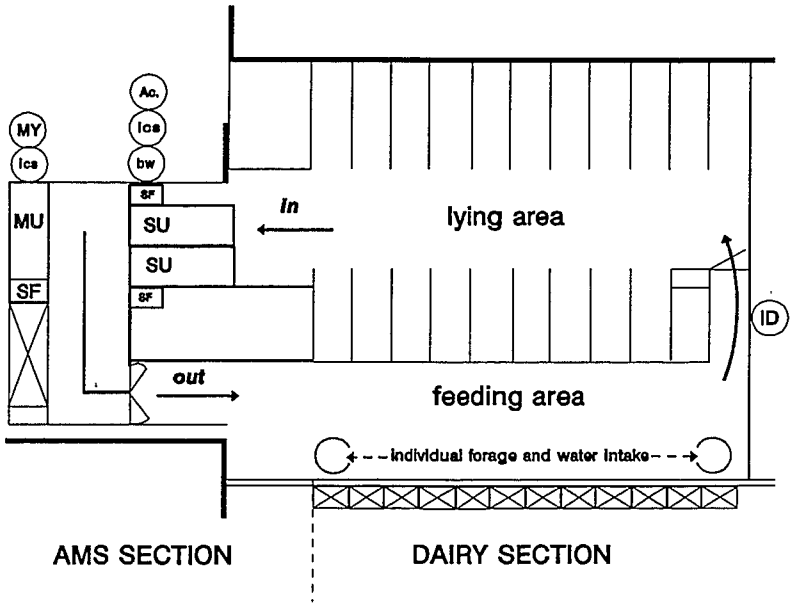
Cow routing

The integration of AMS means that cows are supposed to visit the milking location voluntarily. The following rules for milking are prevalent:

- a cow visiting the AMS is only milked after a predetermined minimum interval and before some maximum interval has passed;
- cows that do not visit the system until the end of the maximum interval are fetched (Devir et al., 1993);
- cows visiting the AMS before the end of the minimum interval are sent away.

Research by Devir et al. (1993) reveals that cows may visit the AMS too early in a substantial number of cases. In order to make efficient use of the milking parlour,

Figure 3 - A diagram of the dairy and AMS implementation on IMAG-DLO experimental farm.



Circles represent on-line data acquisition.

SU = selection unit; MU = milking unit; SF = self feeder; bw = body weight; ID = cow identification each time a cow passes the one-way gate; ics = self-feeder individual concentrates supplementation; Ac. = activity data read from leg pedometers; MY = milk yield, temperature and conductivity. Milk composition was sampled twice a week.

a separate selection unit has been developed for recognition and selection of cows that move to the AMS and have to be milked. The selection unit is located in front of the milking parlour (SU, see Figure 3). Early experiences in automatic milking research showed that cows do not visit the AMS spontaneously at the required frequency without a specific reward. More recent experiments showed that also the supply of concentrates in the milking parlour is no guarantee that fetching is not needed (Ipema and Benders, 1992). Generally, the necessity of fetching seems to be influenced by the lay-out of the system and the behaviour of the animals (Metz-Stefanowska et al., 1992 a and b). On the other hand, there may be strong individual differences between the animals (Devir et al., 1993).

As fetching of cows does not fit so well within the automatic milking concept, it was studied to what extent a forced routing of cows to the AMS would be helpful. Cows in a loose cubicle house could move from the lying to the feeding area only by passing a selection unit in front of the simulated milking parlour (the so-called 'active' selection) (Ketelaar-de Lauwere, 1992). Alternatively, cows could move freely to the selection unit within the preset interval (the so-called 'passive' selection). The results showed that only active selection guaranteed the required number of visits to the milking place for all cows. However, after some weeks of training with active selection, also passive selection was satisfactory. An important conclusion is that a forced routing of cows should always run from the lying area to the feeding area. Cows after milking should eat and stand instead of lying down in order to avoid an increased risk of mastitis (Prospects, 1992).

Milking frequency and milk quality

In spite of the high yields which are achieved on practical farms, most dairy cows are milked twice a day. It is quite clear that from the lactation physiology and animal welfare points of view that it is better to milk cows more often. Some experts even think frequent milking a must (Prospects, 1994). Automatic milking systems offer the possibility of milking more frequently. Besides a higher milk yield it is important -in order to prevent damage to teat tissue and udder- to underline that an individual cow approach for more frequent milking is valuable (Ipema and Benders, 1992).

Automatic milking systems require automatic control of the milk quality. To produce high-quality milk, teat cleaning before milking is necessary. There are several technical possibilities of carrying out this cleaning e.g., by rotating brushes or towels or by spraying water in the teat cups.

Careful hygiene in the cowhouse and milk filtering is still necessary to deliver high-quality milk.

Detection of mastitis is necessary in order to separate lower-quality milk. This detection can be carried out with the help of sensors in the short milktubes which measure the electrical conductivity and temperature of the milk. When a certain threshold value is passed the dairy farmer has to search the cow for veterinary treatment (Maatje et al., 1992).

Labour and Management

Saving time is one of the most important reasons that dairy farmers are interested in

automatic milking devices. Labour time needed for milking is 35-50% of the total time needed for the daily routines in a dairy cowhouse. With regard to the physical work the design of the automatic milking devices is not optimal. This plays a role when attaching the teatcups must be carried out by hand. "Quality of life" can be improved because the dairy farmer can schedule his daily tasks freely, without being tied to traditional milking and feeding times.

A dairy control and management system (DCMS) was developed and tested at IMAG-DLO. The DCMS comprises an input/output interface, a data base and an expert-system (see Figure 4). This system controls the daily milking and concentrates routine, using off-line and on-line data acquisition, processing and operation. The system presents on-line and daily information graphically so that the farmer can change any given decision appropriately.

First results indicate that automatic control of daily milking and feeding routine based on cows' voluntary visits can ensure implementation of predetermined individual milking frequency and concentrates allocation. The use of two selection units (SU) and one milking unit (MU) (see Figure 3) can achieve a daily rate of more than 100 milkings (Devir and Metz, 1994).

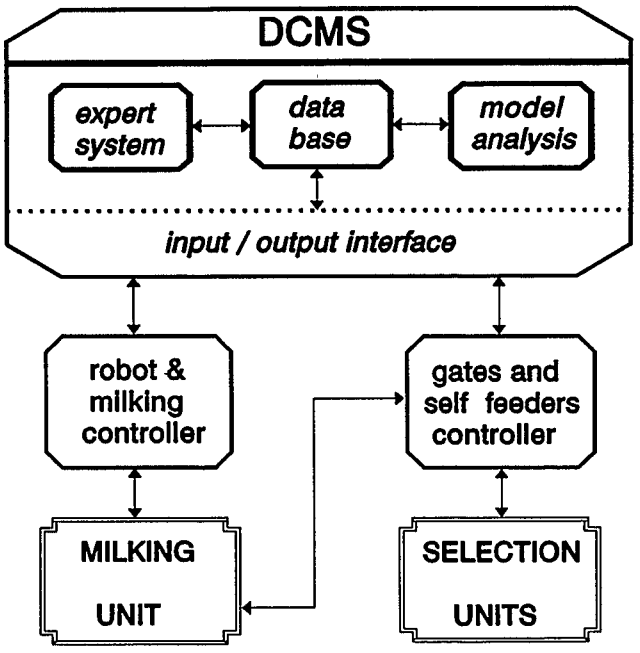
Concluding remarks

In the Netherlands research and development activities are carried out by private companies (Gascoigne Melotte, Lely, Prolion) and research institutions such as IMAG-DLO and the Research and Advisory Station for Cattle, Sheep and Horse Husbandry (PR).

Special attention is also paid to aspects of animal welfare such as cow routing, more frequent milking and health monitoring. Today the state of the art of automatic milking is that the acceptability of the system by dairy farmers can be improved through a more accurate and thus reliable attachment technology (robot/sensor system), the control of the milk quality, the milking technology and the integration of AMS on the dairy farm (eg, combination with grazing). However progress is made, a broader application needs inventive research and development work in the coming years. The main backgrounds for these research and development activities are:

- increasing milk yield per cow, which requires more frequent milking and an individual cow approach for the milking technique and individual monitoring of production, health and animal welfare;
- innovative technology for the future development of dairying;
- work situation in dairy farming.

Figure 4 - AMS management system components.



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